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14. ABSTRACT

Purpose: The study had three aims: 1) Determine the feasibility of quantifying sweat calcium loss during desert physical training, 2) Examine the significance of calcium loss on bone health, and 3) Describe the impact of self-reported exercise and dietary habits on bone health. **Design**: This was a prospective, descriptive, longitudinal study.**Methods**: Sweat collection via patch method occurred during scheduled desert training. Biomarkers of bone turnover, anthropometric measures, and reports of activity and diet via questionnaires, were obtained pre-deployment and within 60 days of return. **Sample**: 156 soldiers participated; 52 completed the sweat collection, and 104 deployed for an average of 12 months. Soldiers represented two types of units, combat support and combat arms. **Analysis**: Tests of change and bivariate correlations were performed to analyze descriptive data; t-tests for independent and paired samples were used where appropriate. **Findings**: A decrease in body weight, BMI, body fat, and waist circumference occurred in both types of units. Physical activity levels declined in each group; two sports activities of moderate intensity and frequency during deployment were significantly correlated with increased heel BMD ($r = .47$, $p = .01$) in combat arms Soldiers. **Implications for Military Nursing**: Brigade nurses and medics are in an influential position to educate soldiers about wellness to include diet, physical activity, and bone health. The deployed environment plays a significant role in the accessibility to resources for a healthy lifestyle and must be evaluated by public health nurses prior to establishing unit wellness goals.

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calcium loss, bone health, deployment health, wellness, healthy lifestyle

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Abstract

The Impact of Sweat Calcium Loss on Bone Health in Soldiers: A Pilot Study

Sixty-eight percent of the current U.S. Army enlisted soldiers are between 17 and 29 years of age. This age range coincides with the period of peak bone mass. There is a possibility that the physical demands and the restricted diet in the deployed environment may be detrimental to bone health.

Purpose: The study had three aims: 1) Determine the feasibility of quantifying sweat calcium loss during desert physical training, 2) Examine the significance of calcium loss on bone health, and 3) Describe the impact of self-reported exercise and dietary habits on bone health.

Design: This was a prospective, descriptive, longitudinal study.

Methods: Sweat collection via patch method occurred during scheduled desert training. Biomarkers of bone turnover, anthropometric measures, and reports of activity and diet via questionnaires, were obtained pre-deployment and within 60 days of return.

Sample: 156 soldiers participated; 52 completed the sweat collection, and 104 deployed for an average of 12 months. Soldiers represented two types of units, combat support and combat arms.

Analysis: Tests of change and bivariate correlations were performed to analyze descriptive data; t-tests for independent and paired samples were used where appropriate.

Findings: A decrease in body weight, BMI, body fat, and waist circumference occurred in both types of units. Physical activity levels declined in each group; two sports activities of moderate intensity and frequency during deployment were significantly correlated with increased heel BMD ($r = .47$, $p = .01$) in combat arms Soldiers.

Implications for Military Nursing: Brigade nurses and medics are in an influential position to educate soldiers about wellness to include diet, physical activity, and bone health. The deployed environment plays a significant role in the accessibility to resources for a healthy lifestyle and must be evaluated by public health nurses prior to establishing unit wellness goals.

TSNRP Research Priorities that Study or Project Addresses

Primary Priority

Force Health Protection:	☒ Fit and ready force ☐ Deploy with and care for the warrior ☐ Care for all entrusted to our care
Nursing Competencies and Practice:	☐ Patient outcomes ☐ Quality and safety ☐ Translate research into practice/evidence-based practice ☐ Clinical excellence ☐ Knowledge management ☐ Education and training
Leadership, Ethics, and Mentoring:	☐ Health policy ☐ Recruitment and retention ☐ Preparing tomorrow's leaders ☐ Care of the caregiver
	☐

Secondary Priority

Force Health Protection:	☐ Fit and ready force ☐ Deploy with and care for the warrior ☐ Care for all entrusted to our care
Nursing Competencies and Practice:	☒ Patient outcomes ☐ Quality and safety ☐ Translate research into practice/evidence-based practice ☐ Clinical excellence ☐ Knowledge management ☐ Education and training
Leadership, Ethics, and Mentoring:	☐ Health policy ☐ Recruitment and retention ☐ Preparing tomorrow's leaders ☐ Care of the caregiver
Other:	☐

Progress Towards Achievement of Specific Aims of the Study

Findings related to each specific aim, research or study questions, and/or hypothesis: The study was developed around the following three specific aims: 1) Determine the feasibility of quantifying sweat calcium loss in Soldiers in a desert climate undergoing intense physical training, 2) Examine the significance of calcium loss on short-term bone health using biochemical markers of bone turnover, as well as dual-energy x-ray absorptiometry (DXA) or heel densitometry to assess bone mineral density (BMD), and 3) Describe the potential impact of self-reported exercise and dietary habits on bone health of Soldiers. Each aim, and the associated research questions, is discussed separately. There are no hypotheses as this is a descriptive study. The following section provides a reference for the effect size and significance of the reported results.

Notes on effect sizes

Cohen's d is a standardized difference, i.e. the mean difference in standard deviation units

- Cohen's d around 0.2 is a small effect size (not likely to be clinically relevant)
- Cohen's d around 0.3 is a small-to-medium effect size and may be considered a clinically relevant effect
- Cohen's d around 0.5 is a medium effect size
- Cohen's d around or greater than 0.8 is a large effect size

For the common Pearson's correlation, a measure of linear relationship:

- Small effect size: |r| of 0.1 (not likely to be clinically relevant)
- Medium effect size: |r| around 0.3 (may be considered clinically relevant)
- Large effect size: |r| around or greater than 0.5

Aim 1. Determine the feasibility of quantifying sweat calcium loss in Soldiers in a desert climate undergoing intense physical training.

Research Question: 1) Is it feasible to quantify dermal calcium loss using a sweat patch technique during vigorous physical activity? Issues regarding feasibility include the ability to obtain Command-level support to recruit and retain a sufficient number of eligible Soldiers and the technical ability to obtain sweat for calcium quantification during actual training.

This phase of the study was completed in September 2008. Coordination with the Unit Senior Leadership (3-2 Stryker Brigade Combat Team on Joint Base Lewis-McChord), resulted in the efficient collection of sweat from 52 Soldiers during desert training at the Yakima Training Center in Yakima, WA. A brief account of the procedure follows:

On 16 Sep 08 and 23 Sep 08, sweat collection procedures were conducted with volunteers in accordance with IRB-approved documents and technical guidance from experts in this field (US Army Research Institute of Environmental Medicine, Gatorade Institute, and University of Texas at Galveston). Following the consent process, each Soldier had two (2) 4 x 4 gauze patches placed on his body by a research team member. One patch was placed on the upper arm and one identical patch was placed on the lower back. Measures were taken to promote adherence to the skin; use of sterile water cleansing of the skin followed by adhesive application using a 2 x 2 swab, and taping of all four (4) sides. The team provided bottled water and annotated the amount consumed. Soldiers performed vigorous physical training for 30-50 minutes. When all Soldiers returned the sweat collection was completed by removing the gauze pads and inserting them into a 60 mL syringe barrel for processing later. Ten (10) mL of sterile water was added to every specimen. All volunteers provided a small specimen for urinary calcium analysis. About 10% of the group voluntarily provided a full-void urine specimen, a pre and post exercise weight, and height in order for a sweat rate to be calculated. Volunteers seemed genuinely interested in the project and willingly submitted to the sweat and urine collections without complaints or concerns. Soldiers did engage in conversation with research team members and asked relevant questions related to mineral losses, hydration, and further research opportunities. The Principal Investigator (PI) processed all specimens immediately upon return to Madigan Army Medical Center, with the assistance of a senior scientist (MJD) in the Department of Clinical Investigations laboratory.

Results: The calcium losses were within the amounts published by other authors, although 10% of volunteers had significantly greater losses than others in the sample population. Reported calcium losses via dermal route (sweat) are from 63 mg/day up to 201 mg/day (or 4.0 to 52 mg/L) depending on the ambient temperature (Consolazio, 1962; Charles et al., 1991, and IOM, 1997). Sweat calcium losses also appear to decline with acclimatization to heat (Consolazio, 1962). Urinary calcium levels were also within published levels with 17% being slightly elevated. One explanation for high urinary calcium losses could be simple dehydration. The research team observed this during the urine collection because urine volumes were often low, and appeared concentrated.

Table 1. Sweat calcium losses

Subjects (N)	**Mean Sweat Ca++**	**Mean Sweat rate (L)**	**Mean Urine Ca++**
Week 1(28) + Week 2 (24) N= 52	.95 $\pm$ .80 mmol/L or 38 $\pm$ 32 mg/L	1.2 $\pm$ .67 L/hr	100.9 $\pm$ 0.6 mg/L
	10% of group > normal Ca++ loss	Range 0-2.4 L/hr fluid loss	Range <10.0 - 290.8 mg/L; 17% of group > normal Ca++ loss

*Normal amount of Calcium in sweat = .4 to 2.2mmol/L or 16 – 88 mg/L
**Normal amount of Ca++ lost in urine = 220 mg/day or about 220 mg/L; somewhat dependent on diet which was not accounted for and usually requires a 24-hr urine specimen.
***Formula for fluid loss:

$$\frac{\text{pre-exercise wt(kg)} - \text{post-exercise wt(kg)} - \text{urine amt out(L)} + \text{fluids in during exercise}}{\text{exercise time in hrs}}$$

The research team feels confident that we met Aim 1 to the extent possible. We were able to recruit a sufficient number of Soldiers (n=52), collect an adequate amount of dermal sweat for calcium analysis, and minimize interruptions in Unit desert training. The Unit Commander was approached early for his support and then briefed on the results which fostered a relationship of professional respect and support for future research endeavors. The educational exchange that took place between research team members and the Soldier volunteers was viewed as very beneficial given that the Unit was deploying soon and would face challenges of heat, dehydration, muscle/bone injuries, and changes to diet and exercise routines. ***Sweat calcium losses appear to be unremarkable for the average Soldier (combat arms) but could contribute to changes in bone mineral density in a small segment of this population who exhibited above normal losses under sustained arid environmental conditions.***

Specific Aims 2 and 3 involved recruitment of a completely different sample of Soldier volunteers. The original study plan was modified to include a comparison group in order to examine differences in nutrition status and bone health between a combat support unit and a combat arms unit. Table 1. and Table 2. display the categorical and some continuous variables of these two units.

Table 1. Demographics of the study sample at baseline

		n	%
Group	Medical	53	50.96
	MP	51	49.04
Gender	Male	79	75.96
	Female	25	24.04
Ethnicity	Caucasian	57	54.81
	African American	23	22.12
	Hispanic	18	17.31
	Asian	3	2.88
	Pacific Islander	2	1.92
	Black, other (e.g. Haitian)	1	0.96
Tobacco use	Don't smoke	63	60.58
	Smoke 2-10 cigs/day	31	29.81
	Smoke 10-20 cigs/day	10	9.62
	Smoke greater than 1 pk/day	0	0
ETOH use	None	40	38.46
	Rare (1 drink per month)	13	12.5
	Occasional (2-3 drinks/wk)	27	25.96
	Moderate to heavy (4-12 drinks /wk)	10	9.62
	Heavy (more than 12 drinks/wk)	14	13.46
Depression	No reported depression	103	99.04
	Reports depression	1	0.96
Eating disorder	No history of eating disorder	101	97.12
	Yes history of eating disorder	3	2.88

Family history of bone disease	No known family history of bone disease	93	89.42
	Known family history of bone disease	11	10.58
History of stress fractures	No history stress fractures	79	75.96
	Positive history of stress fractures	25	24.04

2. Body composition variables (Groups combined)

	Baseline					Follow-Up				
Variable	N	Mean + SD	Min	Median	Max	N	Mean + SD	Min	Median	Max
Age	104	23.1+ 3.02	18	23	31	50	-			
Height (in)	104	69.2 + 4.03	59	70	80	50	-			
Weight (lbs)	104	178.1 + 35.0	102.8	177.3	272	50	180.1+32.2	128	180	262.5
Body mass index	104	25.98 + 3.82	18.7	25.24	34.9	50	26.2 +3.52	18.7	25.8	36
Body fat	104	20.88 + 7.5	5.7	21	39.6	50	19.5 + 7.78*	3.2	19.85	33.5
Waist circum-ference	104	33.6 + 4.6	23	33	48	50	32.6 4.43*	16.5	32.5	41

Aim 2. Examine the significance of calcium loss on short-term bone health using biochemical markers of bone turnover, as well as dual-energy x-ray absorptiometry (DXA) or heel densitometry to assess bone mineral density (BMD).

Research Questions: 1) Will the selected biomarkers for bone turnover correlate with calcium losses quantified in sweat? 2) If there are changes in BMD will they be detected by DXA/Heel bone densitometry over the deployment time period?

Given that the quantity of dermal calcium loss was within normal limits for the majority of Soldiers, we focused more on the overall impact of the deployment on short-term bone health. Reports in the literature demonstrate that DXA can reliably detect changes in BMD in as little as 8 weeks. Deployments in support of Overseas Contingency Operations (OCO) routinely lasted 9-15 months so we used this to define “short-term”. We recruited the initial cohort of Soldiers from a Medical Brigade; they described their jobs as combat medics, ambulance drivers, clerks, and vehicle technicians. The study expanded in 2009 with recruitment of Soldiers assigned to a Military Police (combat arms) Brigade in order to compare effects of deployment by military occupational specialty. This cohort of Soldiers described their jobs as police officers, security guards, and a few combat medics (temporarily assigned for the deployment). The team felt this comparison between combat arms and non-combat arms Soldiers would lead to a greater understanding of the risks to bone health determined by the intensity of one’s work.

We carefully selected biomarkers during the planning stage of the project. Table 2 lists the *original* and *final* selection. Please see the section on the effect of problems/obstacles for further biomarker discussion.

Table 2. Bone health biomarkers

Biomarker	Measurement	Reference
Amino-terminal telopeptide of collagen cross-links (urine) *Original*	Bone resorption	Monitoring Metabolic Status. Predicting decrements in physiological and cognitive performance. IOM, The National Academies Press, Washington, D.C. pp 352-353
Tartrate-resistant acid phosphatase (serum) *Original*	Bone resorption	As above
Bone specific alkaline phosphatase (serum) *Final*	Bone formation	As above
Carboxy-terminal fragment of type I procollagen (serum) *Original*	Bone formation	As above
Osteocalcin (serum) *Final*	Bone turnover	As above
Urinary calcium *Original*	Bone turnover	As above
Insulin-like growth factor 1 (serum) *Final*	Acute/chronic stress & skeletal integrity	As above; pp 374-5
1,25 dehydroxyvitamin D3 (serum) *Final*	Bone integrity	Hollick, 2005
Calcium (serum) *Final*	Bone integrity, metabolic status	Armstrong LE, Szlyk PC, De Luca JP, et al., 1992.

In addition to the standard AP spine and femur bone density scan, bone biomarkers included bone-specific alkaline phosphatase (BS Alk Phos), tartrate-resistant acid phosphatase (TRAP), serum calcium, and osteocalcin initially. Insulin-like growth factor -1 (IGF-1) and 1,25 dihydroxyvitamin D (vitamin D) were added in time for the return of Group 1 and the pre and post-deployment of Group 2 (Table 3.). Serum biomarkers used as explanatory variables for bone health included erythrocyte sedimentation rate (ESR), ultrasensitive thyroid stimulating hormone (TSH), total testosterone (males only), and estradiol (women only) (Table 4.). Body composition measures included height, weight, waist circumference, body fat analysis, and body mass index (Table 2.).

Table 3. Bone Biomarkers

	Baseline					Follow-Up				
Variable	N	Mean ± SD	Min	Median	Max	N	Mean ± SD	Min	Median	Max
BS Alk Phos (M)	10	16.8 ± 3.15	13.8	16.15	23.2	36	16.9 ± 4.56	9.7	16.3	27.4
BS Alk Phos (F)	5	11.3 ± 4.79	7.1	9.9	19.1	9	12.3 ± 4.57	6.7	10.8	19.5
TRAP	48	4.8 ± 1.23	1.4	5	7.2	9	4.22 ± 0.93	2.9	3.9	5.9
Osteocalcin (M)	10	26.6 ± 6.1	19.9	24.5	37.1	11	23.2 ± 4.4	18.3	22.2	30.5
Osteocalcin (F)	5	19.6 ± 9.3	9.5	17.1	32.2	7	17.6 ± 9.3	8.4	16.6	35.7
Calcium	79	9.39 ± .31	8.8	9.4	10.1	49	9.98 ± .43	9	10	10.9

Vitamin D	36	24.2 + 7.9	8	23.5	45	15	30.1 + 16.6	7	27	71
IGF-1	32	290.5 + 62.6	160	284	409	18	219.7 + 67.3	134	201.5	409

Table 3. Serum Biomarkers (Explanatory) **Baseline** **Follow-Up**

Variable	N	Mean ± SD	Min	Median	Max	N	Mean + SD	Min	Median	Max
ESR	82	4.55 ± 3.96	1	3.5	21	21	3.24 ± 2.72	1	2	9
TSH	80	1.46 ± .71	.27	1.31	3.44	48	1.71 ± .79	.4	1.62	4.03
Testosterone (M)*	57	3.66 + 1.3	.39	3.76	6.28	37	10.67 + 6.58	.13	10.0	24.2
Estradiol (F)	6	80.67 + 92.64	20	35	253	5	52 + 47.5	19	30	135

*Significant difference between baseline and follow-up

<u>**Results**</u> (* statistically significant at $p < 0.05$)

1. We noted the following relationships between bone turnover measures and bone mineral density (BMD) at baseline and follow-up (*for Group 1 Medical only*):

Baseline:

<u>Medium effect sizes:</u>

- Osteocalcin with: Femur BMD, Spine BMD
- Bone specific alkaline phosphatase with: Spine t-score

<u>Large effect sizes:</u>

- Bone specific alkaline phosphatase with: Femur BMD, Spine BMD *

Follow-up:

<u>Medium effect sizes:</u>

- Osteocalcin with: Femur t-score
- Bone specific alkaline phosphatase with: Spine BMD
- Tartrate resistant acid phosphatase with: Femur BMD, Femur t-score

<u>Large effect sizes:</u>

- Osteocalcin with: Femur BMD
- Insulin-like Growth Factor 1 with: Femur BMD *, Femur t-score *, Spine BMD *, Spine t-score *

We also examined changes in continuous variables pre- and post-deployment because body fat and body mass index are correlated with BMD. Results include the following:

<u>Small-to-medium effect sizes:</u>

- Body fat (%)*
- Waist circumference *

<u>Medium and large effect sizes:</u>

- Spine BMD

- Supplemental vitamin D *

Results reveal that bone specific alkaline phosphatase (BS alk phos) is a biomarker sensitive to bone mineral density. BS alk phos is an isoenzyme secreted by the osteoblast and is involved in bone mineralization; it is more sensitive and specific than alkaline phosphatase. Bone growth is associated with elevated alk phos levels and it is not unusual for it to be high in adolescents. Group 1 had the benefit of the availability of DEXA and thus, gold standard measurement of spine and femur bone mineral density. It is interesting to note that the large, significant effect size between BS alk phos and spine BMD was detected only at baseline and not at follow up. However the sample size was low at both time points, more so at baseline when the lab test was inadvertently omitted for some Soldiers. There was a slight insignificant increase in BS alk phos for females but not for males over the course of the deployment. These results suggest that bone formation/mineralization remained stable over time for Soldiers 18-30 years of age, regardless of their gender or occupation while deployed.

At the follow up time point, a strong relationship between IGF-1 and femur and spine BMD was detected. This lab test was added late in the study period and only captures the return of Group 1 (Medical), who had no baseline levels, and the baseline of Group 2 who had no follow-up levels reported due to lab failure. IGF-1 levels were essentially normal for all Soldiers who had the test performed, and spine and femur BMD appeared normal and relatively stable from baseline to follow-up. IGF-1 was selected as a biomarker because it is an important contributor to skeletal integrity, as well as an indicator of nutritional (energy) deprivation or depletion. Since nutrient availability was less of a concern during OCO, we anticipated using serum IGF-1 as an indicator of psychological stress. A relationship has been previously described regarding endocrine responses associated with psychological stress and accelerated bone resorption and decreased bone formation (Imeida et al., 1999). Specifically, an increase in cortisol and a decrease in IGF-1 may synergistically decrease bone mass at specific skeletal sites, below the threshold for stress fractures (Munoz-Torres et al., 2001). However, there are no known studies that have examined the association between patterns of the individual stress response and subsequent risk of stress fractures as this would be difficult to measure in the deployed setting (Cizza et al., 2001).

The stress response may also be detected in a relationship between IGF-1 and the reproductive hormones, testosterone and estradiol. Stress manifested by corticotropin releasing hormone (CRH) hypersecretion and hypercortisolism can lead to the inhibition of the reproductive axis which also contributes to decreased activity of the growth hormone-IGF-1 axis, an important enhancer of bone formation. In fact, osteoporosis is a serious medical consequence of chronic stress (Cizza et al., 2001). In this sample of males and females, testosterone increased over the deployment while estradiol decreased. The drop in estradiol level was not significant when one unusually high value was excluded from baseline, since this individual did not return for follow up. It is unclear as to why testosterone levels increased over time. There are reports that androgens and steroid use (by fitness-conscious Soldiers perhaps) can contribute to *reduced* testosterone levels and potentially, hypogonadism. Testosterone levels vary by stage of maturity but normal levels are reported as 1.75 – 8.71 ng/mL and estradiol levels vary by the menstrual cycle phase for women. It does not appear that the reproductive axis was negatively impacted for any Soldier during this deployment.

The pre- and post-deployment relationships between body fat (%) [20.9 $\pm$ 7.5 vs 19.5 $\pm$ 7.8; $\boldsymbol{p = .05}$], waist circumference [31.9 $\pm$ 3.4 vs 35.4 $\pm$ 4.18; $\boldsymbol{p = .01}$], spine BMD [1.25 $\pm$ 0.12 vs 1.25 $\pm$ 0.12; $p = .13$] and supplemental vitamin D [103.6 $\pm$ 175.7 vs 74.5 $\pm$ 138.1; $p = .35$] can be partly attributed to differences detected at baseline between the medical group and the MP group for some of these variables, except spine BMD, and supplemental vitamin D. The supplemental vitamin D relationship reflected a medium to large effect size following deployment, with higher intakes reported by both groups, but substantially more by the MP group (up from 74.5 to 200.9 ng/mL; *p* = .07). Unfortunately, serum vitamin D measurement was not fractionated to distinguish between endogenous versus dietary intake of the vitamin, however, both groups did have an increase in dietary vitamin D according to the Block Food Frequency Questionnaire analysis.

Aim 3. Describe the potential impact of self-reported exercise and dietary habits on bone health of Soldiers.

Research Question: Will data from the Baecke Habitual Physical Activity and the Block 2005 Food Frequency Questionnaires regarding exercise and diet have any correlation with the changes in BMD detected on DXA/heel bone densitometry? Does military occupational specialty impact bone health? Does combat environment impact bone health?Does diet and physical activity differ for combat support vs combat arms Soldiers in such as way as to impact bone health, or health in general?

Prior to the deployment, all participating Soldiers were educated on maintaining their present state of good health in general, and their bone health, specifically. To address bone health a slide presentation about diet choices that included calcium, vitamin D, phosphorus, and protein was provided, and examples of resistance exercises that are beneficial to bones were described. The type, duration, and frequency of exercise performed has been shown to offset decrements in bone density, in fact, it may contribute to an increase in BMD.

With the understanding that contractor-run dining facilities provide high quality food with a variety of fruits and vegetables each day, along with an ample supply of milk and other calcium-containing dairy products, we would expect diet to have a positive effect on bone health in this sample of Soldiers. However, it is necessary to explore the amount of bone-building protein, calcium, phosphorus, and vitamin D consumed in the deployment diet, as reported by the Soldiers, to determine any effect on BMD.

Table 4.

	Baseline					Follow Up				
Variable	N	Mean ± SD	Min	Median	Max	N	Mean ± SD	Min	Median	Max
Total kcals consumed	102	2792 ± 1541.5	765.73	2334.38	8450.0	50	2983.6 + 1943.4	573.4	2442.1	8613.5
Dietary Protein gms/d	102	106 ± 69	26.05	86.6	407.24	50	118.4 + 73	22.8	102.5	371
Calcium (Dietary)	102	1129 ± 640.4	375.01	1036.05	4109.1	50	1203.9 + 653.5	136.6	1027.8	2781.3
Supplemental Calcium	102	122.3 + 270	0	0	1240	50	206.9 + 334.2	0	34.3	1240
Vitamin D (dietary)	102	180 ± 117.3	14.5	163	565.8	50	226 + 148.1	28.8	202.2	593.4
Supplemental Vitamin D*****	102	89 ± 158	0	0	600	50	158.9 + 205	0	0	686
Dietary Phosphorus	102	1691.1 ± 927.7	540.3	1435.1	4982	50	1886.8 + 1078.2	358.5	1681.6	4585.1
*****p<.05										

<u>Results</u> (* statistically significant at $p < 0.05$)

1. The following changes in body composition, BMD, and activity levels were noteworthy between the pre and post-deployment time period, with some being both clinically and statistically significant:

<u>Small-to-medium effect sizes:</u>

- Body fat analysis as % *
- Waist circumference in inches *
- Sport1 Index *

<u>Medium and large effect sizes:</u>

- Spine bone mineral density
- Supplemental vitamin D *
- Work Index *
- Leisure Index *

As previously stated, there were baseline differences in the body composition profiles of Group 1(Medical) and Group 2 (MP); this is not unexpected when considering one is a combat support unit and the other is a combat arms unit. The change in body fat and waist circumference was positive as the mean value for each measure *decreased* over time. Similarly, the intake of supplemental vitamin D *increased*. Unfortunately, the indices of physical activity, namely sport, work, and leisure scores on the BHPAQ, *decreased* over the deployment period. In most cases, Soldiers who reported participating in more than one sport activity prior to deployment were unable to keep this up while deployed, so scores dropped. Commanders try hard to build in time for regular physical activity throughout a deployment but unit mission and location may be limiting factors. Of note is that the work score *decreased* when it is often assumed that the work performed during deployment may be more arduous and of greater duration than when the unit is in garrison. The BHPAQ questions posed were answered using a Likert-type scale; some stems included: At work, I lift heavy loads; After working, I am tired; At work, I sweat; followed by Never, Seldom, Sometimes, Often, and Always.

2. Relationships between *bone turnover measures and calcium & vitamin D intake* from baseline to follow-up: (* statistically significant at $p < 0.05$)

Baseline:

<u>Medium effect sizes:</u>

- Osteocalcin with: Supplemental calcium
- Alkaline phosphatase with: Supplemental vitamin D *
- Insulin-like Growth Factor 1 with: Supplemental vitamin D

<u>Large effect sizes:</u>

- Osteocalcin with: Dietary vitamin D *, Dietary calcium
- Bone specific alkaline phosphatase with: Supplemental calcium

Follow-up:

<u>Medium effect sizes:</u>

- Osteocalcin with: Supplemental calcium

- Bone specific alkaline phosphatase with: Supplemental vitamin D *
- Insulin-like Growth Factor 1 with: Dietary calcium
- Serum vitamin D with: Dietary vitamin D, Supplemental vitamin D, Dietary calcium

<u>Large effect sizes:</u>

- Osteocalcin with: Dietary calcium
- Tartrate resistant acid phosphatase with: Dietary calcium
- Serum vitamin D with: Supplemental calcium *
- C-telopeptide with: Dietary calcium

Choices for bone turnover measures appear to have been appropriate with distinct relationships noted for several of them with dietary intake of vitamin D and calcium. It is clear now that the logistics of organizing a venipuncture station with data collection activities at the unit may result in too many obstacles to proper specimen processing (see section on Problems Encountered). As would be expected, dietary calcium and vitamin D intake were highly correlated, most likely because many foods containing calcium are also fortified with vitamin D.

4. Relationships between *bone mineral density and calcium & vitamin D intake* from baseline to follow-up:

Baseline:
No relevant relationships observed

Follow-up:
<u>Medium effect sizes:</u>

- Femur BMD, Spine BMD, Spine t-score, Heel BMD, Heel t-score with: Dietary calcium

The only comment to make regarding BMD and dietary intake of calcium and vitamin D is that Group 2 (MPs) who underwent heel densitometry for BMD upon return from deployment only, had the strongest relationship between BMD and dietary calcium, but this was not statistically significant, $p = .08$.

5. Relationships between *activity and diet, and bone turnover measures* from baseline to follow-up:

Baseline:
<u>Medium effect sizes:</u>

- Tartrate resistant acid phosphatase with: Daily calories consumed, Dietary carb intake
- Serum vitamin D with: Daily calories consumed, Dietary protein intake, Dietary carb intake, Dietary phosphorus

<u>Large effect sizes:</u>

- Osteocalcin with: Daily calories consumed, Dietary protein intake *, Dietary fat intake, Dietary carb intake, Dietary phosphorus
- Serum vitamin D with: Dietary fat intake *

Follow-up:
<u>Medium effect sizes:</u>

- Insulin-like Growth Factor 1 with: Dietary phosphorus
- Serum calcium with: Leisure Index
- Serum vitamin D with: Dietary phosphorus, Leisure Index

- C-telopeptide with: Sport 1 Index, Leisure Index

<u>Large effect sizes:</u>

- Osteocalcin with all measures: Daily calories consumed *, Dietary protein intake *, Dietary fat intake *, Dietary carb intake *, Dietary phosphorus *, Work Index, Sport 1 Index, Sport 2 Index, Leisure Index
- Insulin-like Growth Factor 1 with: Daily calories consumed *, Dietary protein intake, Dietary fat intake, Dietary carb intake, Work Index, Sport 1 Index, Sport 2 Index, Leisure Index
- Tartrate resistant acid phosphatase with: Daily calories consumed, Dietary protein intake *, Dietary fat intake *, Dietary carb intake, Dietary phosphorus, Work Index, Sport 1 Index, Sport 2 Index, Leisure Index
- Serum calcium with: Work Index
- Serum vitamin D with: Work Index, Sport 1 Index
- C-telopeptide with: Daily calories consumed *, Dietary protein intake *, Dietary fat intake* Dietary carb intake *, Dietary phosphorus *, Work Index

The strong relationships identified between bone turnover markers, activity levels, and diet again indicate a good selection of sensitive serum biomarkers. However, the only bone turnover marker measured in both groups, at both time points, was serum calcium. While it is important to note that many diet and activity measures were moderately associated with serum calcium levels, none were statistically significant. Overall, both groups reported an increased consumption of calcium and vitamin D during the deployment which could be reflected in the increase in mean serum calcium level. Likewise, the increase in consumption of bone-building calcium and vitamin D may explain the relationship between lower physical activity scores and maintenance of good BMD.

6. Relationships between *activity and diet, and BMD measures* from baseline to follow-up:

Baseline:

<u>Medium effect sizes:</u>

- Work Index with: Femur BMD, Spine BMD*

Follow-up:

<u>Medium effect sizes:</u>

- Daily calories consumed with: Spine BMD
- Dietary fat intake with: Spine BMD
- Dietary carb intake with: Femur BMD, Heel BMD *
- Dietary phosphorus with: Spine BMD, Heel BMD
- Dietary calcium with: Spine BMD, Heel BMD
- Work Index with: Spine BMD
- Sport1 Index with: Femur BMD, Heel BMD
- Leisure Index with: Femur BMD

<u>Large effect sizes:</u>

- Daily calories consumed with: Heel BMD *
- Dietary protein intake with: Spine BMD, Heel BMD *
- Dietary fat intake with: Heel BMD *
- Dietary carb intake with: Spine BMD

- Sport 1 Index with: Spine BMD
- Sport 2 Index with: Spine BMD

The results for baseline, or pre-deployment, represent only Group 1 (Medical) who had Spine and Femur BMD measured by DXA, and demonstrate that there was a significant relationship between the moderate levels of physical activity in their job and spine BMD (r = .28, p = .05). Work index was moderately correlated with femur BMD but not significant (r= .26, p = .07).
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The results for post-deployment, or follow-up, show some important relationships between diet, physical activity, and bone mineral density (see Table 6.). Protein intake averaged 1.7 gms/kg in Group 1 and 1.29 gms/kg in Group 2. While protein intake is important for bone growth and strength, the intake by both groups exceeds the DRI of 0.8 gms/kg/day for adults, which may explain the robust correlation with bone density. Physical activity scores of the Medical group were moderately to strongly correlated with femur (r = .33) and spine (r = .68) BMD but did not achieve significance, most likely due to small numbers of Soldiers. Physical activity scores for Group 2 (MPs) were not correlated with heel BMD; this may be due to the fact that there was only one measure of heel BMD, post-deployment, for this group.

Table 5. Group 1 & 2 Baseline and Follow-Up Physical Activity

Index	Group Code	N	Mean	SD	Std. Error Mean	t	Sig. Two-tailed
Sport 1 Index Pre-deployment	Medical	52	2.46	.72	.101	-3.36	**0.001**
	MP	51	2.88	.51	.071		
Sport 1 Index Post-deployment	Medical	19	2.59	.81	.186	-1.46	0.151
	MP	24	2.91	.64	.131		
Sport 2 Index Pre-deployment	Medical	31	2.69	.54	.097	-2.39	**0.021**
	MP	22	3.01	.36	.078		
Sport 2 Index Post-deployment	Medical	18	2.36	.92	.217	-1.54	0.135
	MP	14	2.82	.72	.193		
Work Index Pre-deployment	Medical	52	2.50	.31	.043	-11.63	**<.001**
	MP	51	3.33	.41	.058		
Work Index Post-deployment	Medical	19	2.23	.38	.381	-10.19	**<.001**
	MP	29	3.25	.31	.311		
Leisure Index Pre-deployment	Medical	52	2.52	.66	.658	-5.51	**<.001**
	MP	51	3.31	.80	.798		
Leisure Index Post-deployment	Medical	19	2.73	.74	.743	-3.07	**.004**
	MP	29	3.34	.68	.632		

*Range of scores is 1-4 per index. Not all participants reported a second sport activity.

We recruited a suitable comparison group for this study by adding a combat arms unit (Group 2, MPs) that clearly discriminates levels of physical activity. Table 5 shows significant differences in self-reported work, sport, and leisure activity scores between groups. The Sport Index for both one and two sporting activities went down for the two groups reflecting less time for recreational activities during deployment. At baseline there was a statistically significant difference in scores for one sport and two sports but this difference was no longer significant upon their return. The mean scores for the groups are appreciably different but the small sample size for returning Soldiers limits the ability to detect a difference in physical activity habits.

Table 6. Group 1. & Group 2. Association of diet & activity with BMD Post-deployment

Pearson Correlation Coefficients Prob > |r| under H0: Rho= 0 Number of Observations			
	femrBMD2	**L_SBMD2**	**HeelBMD2**
KCALS Post	0.214 0.409 17	0.398 0.114 17	0.400 0.035 28
DT Protein Post	0.126 0.630 17	0.418 0.095 17	0.416 0.028 28
DT Fat Post	0.156 0.550 17	0.356 0.160 17	0.404 0.033 28
DT Carb Post	0.278 0.279 17	0.402 0.109 17	0.400 0.035 28
DT Phos Post	.176 .499 17	.393 .1182 17	0.349 0.070 28
Work Index Post	0.242 0.602 7	-0.356 0.434 7	.113 0.558 29
Sport 1 Index Post	0.333 0.465 7	0.681 0.092 7	.343 0.070 29
Sport 2 Index Post	0.212 0.648 7	0.516 0.236 7	0.466 0.010 29
Leisure Index Post	-0.369 0.415 7	-0.187 0.688 7	-0.01 0.940 29

KCALS = calories consumed; DT = Dietary; Post refers to Post-Deployment;
Carb = Carbohydrate; Phos = Phosphorus

Relationship of current findings to previous findings:

We conceived this study idea before there were any reports of research done in military populations that examined sweat calcium loss, or nutrition status and bone health before and after deployment. One of the earliest studies (Klesges et al. 1996) prompting this work reported high dermal calcium losses in the amount of 247 mg per training session for college basketball players. The investigators were able to link decreases in total bone mineral content (6.1% overall, 10.5% in legs) to the high calcium losses. In a subsequent study an intervention involving calcium supplementation was associated with significant increases in bone mineral content over a period of one year. While the vigorous exercise periods lasting up to two hours twice a day are not typical for a combat arms Soldier, this level of exercise may occur during a land-based deployment to dry, arid climates like Iraq and Afghanistan. While the intent of this research was not to monitor calcium losses via sweat long-term, Aim 1 informed the remaining aims and allowed the team to include specific information about calcium homeostasis in their educational efforts for all Soldiers scheduled for deployment. Current published reports in the literature regarding sweat calcium losses involving the military population refer to work done by a team of scientists at the US Army Research Institute of Environmental Medicine (USARIEM). Their work has focused on different methods to collect sweat, most recently announcing the development of a Megaduct sweat collector for mineral analysis (Ely et al. 2012). Their results are congruent with those reported in this paper. Another paper (Montain et al. 2007) published by the USARIEM team reports that levels of minerals lost in sweat to include sodium, potassium, and calcium remain constant over multiple hours of exercise-heat stress. In fact, the mineral losses during 7 hours of sustained sweating could be predicted from the initial sweat composition. Only zinc appears to be conserved over time, with poor predictability. These results are very informative for the current research team who will be able to incorporate such information on physiologic measures into ongoing studies.

Over the past 5 years there have been a few published descriptive studies (Lester et al. 2010; Sharp et al. 2008) about the effects of a long-term land-based deployment on body composition, bone density, and physical fitness in military personnel. The study by Sharp et al. (2008) was similar to this study in its timing of measurements, 30-60 days pre-deployment, with follow up measures as soon as possible following deployment. Also similar were height, weight, and DXA methodologies. Our study may be the only study examining calcaneal bone density using ultrasound. It was very interesting to note that the 110 Soldiers who completed post-deployment measures in the Sharp et al. (2008) study reported a lower frequency and intensity of exercise; this closely parallels the physical activity results in this study regarding work, leisure and sport activity captured by the Baecke Habitual Physical Activity Questionnaire (BHPAQ).

In the Sharp (2008) paper, of the 135 Soldiers who completed pre-deployment testing, 14 Soldiers did not complete post-deployment testing due to injury, illness, permanent change of station, temporary duty in other locations, or no-shows for testing. While reasons for incomplete data are the same, the current study experienced a much higher attrition rate than the 10% reported by Sharp (2008); for both the Medical and the MP group, attrition was closer to 50%. They also report that body mass index and fat-free mass decreased from pre-deployment to post-deployment, whereas percent body fat and fat mass increased during this same timeframe. Contrary to these data, in the current study, Soldiers maintained body mass index at similar levels, but decreased body fat percent significantly (mean change = -1.4; p=.04). Even more impressive was the significant decrease in waist circumference (mean change = -1.29; p=.01) in this study population. Lastly, of relevance to the current study is the report by Sharp (2008) that there were small decreases in bone mineral content and bone mineral density; however, the change in bone mineral density did not exceed the precision of the measurement tool (T score ±1%). Similarly, in this study there were no significant changes in BMD for the femur, L-S spine, or heel when compared pre- and post-deployment. There was a select group of Soldiers who experienced a concerning decline in their bone density (T score > -1%) that might warrant further work-up by the health care provider. In Group 1 approximately 20% of readings reflected a decrease below the acceptable threshold (using DXA), and 10% of readings in Group 2 were below the threshold (using calcaneal ultrasound) established by the World Health Organization for healthy young adults. There is a lack of literature comparing bone density readings between DXA and calcaneal ultrasound measurements.

Another recent paper by Lester et al. (2010) examined combat arms Soldiers before and after a 13-month deployment to Iraq. Many measures were similar to the current study. It is particularly interesting to note their report of decreased physical activity during deployment, aerobic exercise and sports in particular. Soldiers compared levels of physical activity to the previous year, just as in the current study. We now have three studies reporting similar results. Lester (2010) and his team state that individual U.S. Army units have expressed concerns about decreases in strength following deployment, as well as decreases in lean body mass and increased fat mass. Until now, no study has validated these concerns. Lester (2010) found that Soldiers experienced a 2.9% increase in body mass and a 4.7% increase in percentage of body fat during deployment. On the contrary, this study found Soldiers had no significant change in body mass index, a decrease of 1.4% (p = .05) in body fat, and -1.29% change in waist circumference (p = .01). Regarding sports activity reported in the Lester (2010) paper, 85% of Soldiers participated in sports for at least 30 minutes per session prior to deployment, but only 35% continued this pattern during deployment. In this study, there was a statistically significant difference in the Sport Index for participation in both one sport and two sports between combat arms and combat support units at baseline; combat arms Soldiers reported a greater intensity and frequency of sports activity. This difference was no longer significant in the post-deployment period although post-deployment scores were slightly higher for one sport, but considerably lower for a second sport for both types of units. There were significant differences between combat support and combat arms for work index and leisure index scores post-deployment; 2.23 vs 3.25, $p < .001$ and 2.73 vs 3.34, $p < .001$ respectively. Overall, Soldiers who indicated a high level of activity at work, also reported high levels of activity for sports, and leisure which may indicate that a Soldier who makes exercise or physical activity a part of his/her lifestyle incorporates this into all aspects of daily life.

Many aspects of diet were strongly correlated, such as the intake of vitamin D and calcium, and both of these were significantly correlated to total calories, carbohydrate, fat, and protein intake. For Group 1 (Medical) overall diet did not have an impact on bone density. For Group 2 (MP) all dietary components were significantly correlated to heel bone density following deployment. While this is an important finding, without baseline heel bone density for this group we do not know if the diet, high in calories, protein, and carbohydrates, with adequate amounts of calcium and vitamin D, actually improved bone density or simply maintained it. Participating in two sports while deployed, with a mean score of 2.36 (range 0-4) for Group 1 and a mean score of 2.8 (range 0-4) for Group 2, was significantly correlated with all dietary components. This might imply that Soldiers who made time for two sports activities while deployed needed greater intake of macronutrients for energy. Group 2 (MP) started out taller and heavier than Group 1 (Medical) which might be expected for a combat arms unit. Group 2 reported more sports activity with resulting decline in body fat and waist circumference. Body mass index (BMI) increased slightly but lean mass weighs more than fat mass which could explain this increase. Even with lower sport scores Group 1 also decreased in mean weight, BMI, body fat, and waist circumference from pre-deployment to post-deployment.

While not evident pre-deployment, total calories, carbohydrate, protein, fat, and phosphorus were all strongly correlated with select bone turnover markers post-deployment, to include Osteocalcin (bone turnover), IGF-1 (skeletal integrity), telopeptide (bone resorption), and tartrate-resistant acid phosphatase (bone resorption). Only protein was not significantly correlated at this time point. It was interesting to see that no dietary component was significantly correlated with calcium or vitamin D serum levels. Calcium and vitamin D intake for both groups met the Dietary Reference Intake (DRI), pre- and post-deployment. Of note, 25/104 (24%) Soldiers admitted to a history of stress fractures upon enrollment in the study. Only 2/48 (.04%) returning Soldiers experienced a new stress fracture while deployed.

Effect of problems or obstacles on the results: 1. Attrition. In the research literature, attrition rates of 20% or less are considered acceptable, with regard to follow–up data collection (Stinner & Tennent, 2012). Military populations present unique challenges for retention. This is due to factors such as reassignment of service members within the military, service members exiting the military following basic training or upon completion of their tour of duty, and unplanned discharge from the military due to misconduct, AWOL status, criminal behavior, or something as simple as failure to meet weight standards. During times of deployments, service members may be injured in combat and will return to their base for medical care. All of these situations lead to attrition from research studies and frequently impact the follow-up data collection. In this study, both Group 1 (Medical) and Group 2 (MP) experienced a high 50% attrition rate. While this was taken into consideration during the planning of the project, the variable “n” for all data points most likely affected the probability of committing a Type II error. It is also possible that the low subject numbers and numerous statistical tests resulted in a Type I error. It does appear that missing data for those participants lost to follow-up were random, therefore this was not something we could accommodate with statistical procedures. Future studies involving the military population will use this information when calculating sample size.

2. Incomplete biomarker assessment. Tremendous effort was exerted coordinating biomarker specimen collection from all soldiers. Because the study team had to reach out to a deploying unit on another Army base (Texas) at great distance from the primary research site for the comparison group, control over some aspects of the data collection was suboptimal. The laboratory facilities at the Texas site were limited in the ability to perform the same analyses as the laboratory at the Washington site. In addition, even after coordinating the specific tests that *could* be analyzed with the Officer-in-Charge, the lab performed the wrong tests and the intended comparisons with previously collected data were no longer possible. We found out later that the Soldier Readiness Center (SRC) lab did not fall under the medical center leadership so communication about these study issues never took place. This could not have been predicted nor could anything be done about it after the fact. Another reason for the discrepancy in the number of lab tests performed is that after the study began there were new concerns about vitamin D status and long-term stress on bone health, so additional measures (vitamin D, IGF-1) were added to the biomarker profile later in the study.

Heel bone density using portable ultrasound densitometry was a biomarker added to the study when it became clear that the comparison group would not have access to full body DEXA (dual energy xray absorptiometry) using a hospital-based scanner like the original group. While the equipment performed valid and reliable measurements and received regular maintenance and quality checks prior to use, the airplane transport to Texas led to a malfunction that could not be corrected during the planned baseline data collection. This resulted in no bone density measurements at baseline for the comparison group, Group 2 (MP). The two study groups were able to be compared for several other measures pre- and post-deployment.

Limitations: This study has several limitations.
Design: The military population recruited for this study were all Army service members. While most were stationed at Joint Base Lewis-McChord, the combat arms group was recruited from Ft. Bliss, Texas. All Soldiers in the assigned groups worked together in either a Combat Support Hospital or a Military Police Unit. While the study aims were expanded in 2008 and resulted in the addition of a comparison group, the study still lacked a control group. A group of Soldiers who were not deploying who could be enrolled with exposure to the same measures before and after a 12-month period. The research team worked diligently to find a non-medical comparison group in hopes of demonstrating that a higher burden of work did negatively impact bone density. This result was not obtained but there was no time or funding left to identify a suitable control group.

Questionnaires: It is possible Soldiers shared answers on the questionnaires but more importantly, questionnaire data were acquired by 'self-report' which is heavily scrutinized as unreliable by many investigators. The questionable validity of answers was further compounded by asking Soldiers to recall a year long period of diet and exercise habits. The Block Food Frequency Questionnaire was not developed with active young adults in mind, especially service members who often exert extreme amounts of energy in the performance of their job while deployed. It was a common complaint that participants could not select the true amount of food consumed in certain categories; cereal for example. The questionnaire is accompanied by photos of small, medium, and large portion sizes but often times a Soldier needed to select even larger portion sizes than offered.

Sample: While the study sample reflects a good mix of gender and ethnicity, investigators could have strived for even more women. There are numerous publications about nutrition status and bone health in female athletes but there is much less written about these two health-related concepts in the female Soldier. This makes the results less generalizable, especially to females in other military services where the work performed could be vastly different.

Logistics: Perhaps the most frustrating part of this multi-phase study was accepting the delays in recruitment and data collection related to the deployment time schedule. Synchronizing the leadership support with the IRB amendment approval was extremely challenging. Two large units identified for participation (3-2 SBCT and 555th Combat Engineers) both deployed prior to receiving the IRB approval to conduct recruitment activities. When the PI was instructed to find an alternate unit as soon as possible, the team reached out to the Western Region Medical Command for assistance. This led to a letter of support from the Commander of the 92nd MPs on Ft. Bliss, TX. The logistical challenges to conducting the study outside of the research team command post (JBLM/Madigan AMC) were never ending. Inadequate pathology support, transporting numerous supplies via plane, and the unavailability of a DXA scanner, nearly compromised the entire research plan. While some measures ended up being less than optimal for comparison, the team made it work.

Conclusion:

In summary, deployment conditions did not appear to negatively impact nutrition status or bone health in either a combat support unit or a combat arms unit. The level of daily work activity reported on the BHPAQ was moderately and significantly correlated with bone mineral density at the pre-deployment period. Work-related activities were no longer associated with bone mineral density at the post-deployment period but sports activity was, with two sports more strongly correlated with heel BMD (r = .47, p = .01) than one sport (r =.34, p = .07), and a strong but non-significant correlation with spine (r =.52) and femur (r = .68) BMD. Consumption of most nutrients was adequate with intake levels exceeding 100% for a subset of dietary components to include protein, carbohydrate, fat, phosphorus, sodium, and vitamin K. Today's deployed environment, Iraq or Afghanistan, is vastly different from the combat environment of previous wars. For the majority of Soldiers, a dining facility is now nearby with a wide array of nutritious options; MREs or any type of field rations are consumed less frequently compared to the past. In addition, a gym or other fitness center is usually close by with all the necessary equipment to promote bone health and wellness; weight-lifting apparatus, elliptical machines, indoor cycling bikes, basketball courts, etc. Despite the availability of nutritious foods and recreational equipment, not all Soldiers will make choices that support a healthy lifestyle. This study with multiple different groups of Soldiers from both combat arms and combat support units demonstrated that a 12-month deployment does not necessarily deplete nutrient stores or exercise capacity. In general, Soldiers reported less physical activity during deployment which presents potential risks for decreased strength, endurance, and physical performance of Soldiers which could lead to musculoskeletal injuries, stress fractures in particular. Soldiers in all types of units must be educated about how to remain fit and healthy when in the deployed environment where there will be significant changes to their garrison routine.

Significance of Study Results to Military Nursing

We now know that the fears of deployment contributing to increased musculoskeletal injuries or decrements in physical performance can be offset by a healthy diet and a sustained effort to remain physically active. We have learned from other recent studies (Barry 2011) that calcium lost via sweat can decrease bone density but acute calcium ingestion before exercise can attenuate this decrease brought about by enhanced parathyroid hormone release. The Soldiers in this study did not experience a decrease in bone density over the course of a 12-month deployment, but levels of activity for work, sports, and leisure were reportedly low. It is possible that decrements to bone density can occur while in garrison if the workload intensity and frequency is elevated. Further research is needed to compare garrison activities to those occurring during deployment.

There are several studies (Sharp 2008; Lester 2010) in the literature that report findings similar to those in this study. We are beginning to compile a library of work that depicts the typical activities of today's Soldiers. It is important for Brigade nurses to understand the health and wellness challenges faced by Soldiers and to establish educational offerings proactively. Medics, physician assistants, and Brigade nurses all have a role in educating, advising, monitoring, and treating Soldiers as part of the Soldier-Centered Medical Home initiative. It is studies like this one that inform the education agenda; more attention must be paid to bone health and the diet and exercise choices that influence it. It is crucial that young soldiers who have not yet reached peak bone mass understand the importance of a diet rich in calcium and vitamin D, as well as weight bearing exercises, to build strong bones and remain a fit and healthy soldier for the duration of their military service.

Much more research is needed on motivation and behaviors in order to better understand choices made by Soldiers that impact their health and wellness. In addition, we do not yet fully understand the genetic influences related to weight, exercise, and diet. Much more work must be done in this field so that factors that can be modified become the target of our efforts. With downsizing efforts underway in the Army, overweight and unfit Soldiers will be the first ones approached by Commanders for involuntary discharge. Whether in a combat environment or a garrison community, Soldiers need support from the leadership and the health care team to remain fit and ready.

When the study was designed based on the input from Commanders on JBLM who had deployed, the team was certain it would uncover a significant relationship between the wearing of body armor and the subsequent musculoskeletal injuries following deployment. The results did not support this early theory. Soldiers did not complain about the weight of the body armor nor did they report a high injury rate or joint pain. With a low rate of Soldiers returning for follow up, it is possible that those who were injured or otherwise incapacitated did not come back and report such complaints. It remains unknown whether or not the heavy body armor combined with the burden of work in theaters of operation lead to long-term musculoskeletal dysfunction and/or disability. This represents yet another component of readiness that is a high priority of unit Commanders.

Changes in Clinical Practice, Leadership, Management, Education, Policy, and/or Military Doctrine that Resulted from Study or Project

None to date. Will be reported when known.

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Summary of Dissemination

Type of Dissemination	**Citation**	**Date and Source of Approval for Public Release**
Publications	McCarthy, MS, Loan, LA, Azuero, A and Hobbs, C. Consequences of modern military deployment on calcium status and bone health. Nursing Clinics of North America, 45: 109-122, 2010.	Madigan AMC Public Affairs Office (PAO) 20 August 2009
Publications in Press	Carlson, AR, Smith, MA, McCarthy,MS. Diet intake, physical activity, and bone density in Soldiers before and after deployment. Submitted to AMEDD Journal for Spring 2013 edition.	Madigan AMC Public Affairs Office (PAO) 13 January 2013
Published Abstracts		
Podium Presentations	1. Bone health status of Soldiers pre- and post-deployment. State of the Science Congress on Nursing Research. Washington, D.C. 27 September 2010	Madigan AMC Public Affairs Office (PAO) August 2009

Poster Presentations	1. The impact of sweat calcium loss on bone health in Soldiers: A pilot study. Karen A. Reider Session at AMSUS. Salt Lake City, UT. 12 Nov 2007 2. Baseline anthropometrics & bone health status in Soldiers prior to OIF deployment. Karen A. Reider Session at AMSUS. 2008 3. Baseline anthropometrics & bone health status in Soldiers prior to OIF deployment. Phyllis J. Verhonick Research Course, San Antonio, TX. 2008 4. Bone health in Soldiers pre-and post-deployment. Karen A. Reider Session at AMSUS. St. Louis, MO. 16 Nov 2009	Madigan AMC Public Affairs Office (PAO) 17 August 2007 5 February 2008 5 February 2008 24 July 2009
Media Reports	1. The Wear and Tear of War: A Program of Research Dedicated to Bone Health in Young Warriors. Army Nurse Corps Newsletter, Vol 36, No 1, March 2011.	Madigan AMC Public Affairs Office (PAO) 8 March 2011
Other Master's thesis [secondary data analysis]	1. Diet intake, physical activity, and bone density in Soldiers before and after deployment. U.S. Army Baylor Program for Dietetics, 1LT A. Carlson, June 2011. 2. Vitamin D, calcium, and bone mineral density post-deployment: A cross-sectional study. U.S. Army Baylor Program for Dietetics, 1LT E. Thompson, June 2011.	Approval received from Baylor University Faculty and the Army Medical Department Center and School June 2011

Reportable Outcomes

Reportable Outcome	Detailed Description
Applied for Patent	None
Issued a Patent	None
Developed a cell line	None
Developed a tissue or serum repository	None
Developed a data registry	None

Recruitment and Retention Table

Recruitment and Retention Aspect	Number
Subjects Projected in Grant Application	300
Subjects Available	188
Subjects Contacted or Reached by Approved Recruitment Method	188
Subjects Screened	165*
Subjects Ineligible	20
Subjects Refused	28
Human Subjects Consented	165
Subjects Group I (Combat Support) / Comparison (Combat Arms) Group II/Group III (Sweat collection only)	53/51/52
Group I / Group II Subjects Who Withdrew	56**
Group I / Group II Subjects Who Completed Study	100
Group I / Group II Subjects With Complete Data (varies by measure)	50
Group I / Group II Subjects With Incomplete Data	50

*After the study briefing in El Paso 23 Soldiers left the room, electing not to participate. **One Soldier in Group 2 did not deploy so he withdrew. One female in Group 2 returned but walked out at the post-deployment data collection. The remaining 31 never returned for follow-up data collection.

Demographic Characteristics of the Sample

Characteristic	
Age (yrs)	23 ± 3
Women, n (%)	25 (24%)
Race	
White, n (%)	57(55%)
Black, n (%)	23 (22%)
Hispanic or Latino, n (%)	18 (17%)
Native Hawaiian or other Pacific Islander, n (%)	3 (.03%)
Asian, n (%)	2 (.02%)
Other, n (%)	1 (.01%)
Military Service or Civilian	
Air Force, n (%)	( )
Army, n (%)	104 (100%)
Marine, n (%)	( )
Navy, n (%)	( )
Civilian, n (%)	( )
Service Component	
Active Duty, n (%)	104 (100%)
Reserve, n (%)	( )
National Guard, n (%)	( )
Retired Military, n (%)	( )
Prior Military but not Retired, n (%)	( )
Military Dependent, n (%)	( )
Civilian, n (%)	( )

Final Budget Report